

# IMPROVE

Volume 2, No. 1

Winter 1993

April 1993

## IMPROVE MONITORING UPDATE

Preliminary data collection statistics for the Winter 1993 season (December 1992 - February 1993) are:

Data Type	Collection Percentage
Aerosol Data	96%
Optical (transmissometer) Data	76%
Scene (photographic) Data	82%

Figure 1 is a map of the current IMPROVE and IMPROVE Protocol sites. Network changes in the last quarter included the installation of NGN-2 ambient nephelometers at Okefenokee, Upper Buffalo, Mammoth Cave, and Mount Rainier. Eight more nephelometers are scheduled for installation during the next three months.

Aerosol data for the Summer 1992 season is complete and seasonal summaries have been submitted to the NPS. Analyses of Fall 1992 and Winter 1993 data are underway. The recovery rate of aerosol data for the Winter 1993 season was 96%, the highest to date.

Reprocessing of all transmissometer optical data from Spring 1991 through Fall 1992 was completed and delivered in March 1993.

An effort is now underway to reprocess and replot all IMPROVE transmissometer data from December 1987 through December 1992 to incorporate newly refined lamp drift correction factors. A comprehensive data report will be delivered in June 1993.

Winter 1993 optical data (December 1992 - February 1993) is currently being compiled and will be reported in May 1993.

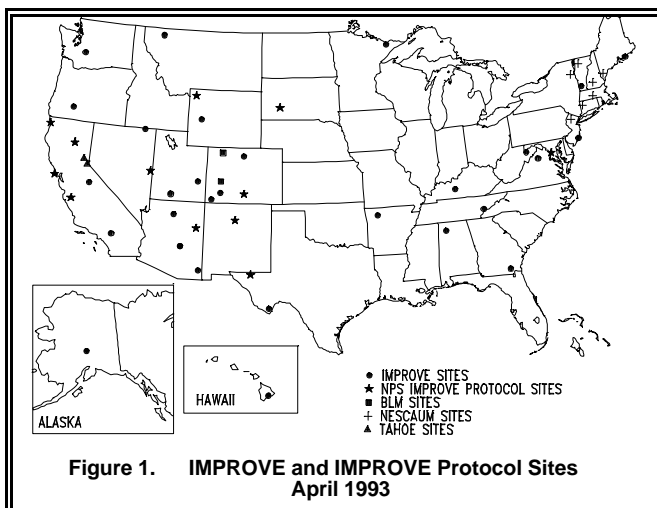


Figure 1. IMPROVE and IMPROVE Protocol Sites  
April 1993

### Feature Article

## DECIVIEW, A STANDARD VISIBILITY INDEX

### INTRODUCTION

An easily understood visibility index (Pitchford and Malm, 1993) has been developed to uniformly describe levels of monitored and modeled visibility impairment and to assess the progress of visibility protection programs.

The scale of this visibility index, expressed in deciview ( $dv$ ), is linear with respect to perceived visual changes over its entire range, analogous to the decibel scale for sound. This article explains this new index and provides examples of its application.

### BACKGROUND

Visibility is traditionally described by visual range (the greatest distance that a large, dark object can be seen) or by the light extinction coefficient (the attenuation of light per unit distance due to scattering and absorption by gases and particles in the atmosphere).

Visual range (expressed in kilometers or miles) was developed and continues to function well as an aid in military operations and transportation safety. It is likely to remain a popular measure of atmospheric visibility because of its familiar distance units, simple definition, and the fact that any sighted person can use it to characterize visual conditions without instruments.

Extinction coefficient (expressed in  $\text{km}^{-1}$ ) is used by scientists studying the causes of reduced visibility. Direct relationships exist between concentrations of atmospheric constituents and their contribution to extinction coefficient. Apportioning extinction coefficient to atmospheric constituents provides a method to estimate change in visibility caused by change in constituent concentrations. This methodology, known as extinction budget analysis, is important for assessing visibility consequences of proposed pollutant emission sources, or for determining the extent of pollution control required to meet a desired visibility condition.

Neither visual range nor extinction coefficient is linear to perceived visual scene changes caused by uniform haze. For example, a 5km change in visual range or a  $0.01\text{km}^{-1}$  change in extinction coefficient can result in a scene change that is either imperceptible or very obvious, depending on the baseline visibility conditions.

## DECIVIEW *(continued from page 1)*

Presentation of visibility data or model results in terms of visual range or extinction coefficient creates the potential for misinterpretation by those who are not aware of the non-linear relationship, and requires the inconveniences of further analysis for those who are aware.

### VISIBILITY INDEX

The newly-developed visibility index's  $dv$  scale is linear to humanly-perceived changes in visual air quality. A one  $dv$  change is approximately a 10% change in the extinction coefficient, which is a small, but usually perceptible scenic change. The  $dv$  scale is near zero for a pristine atmosphere ( $dv = 0$  for Rayleigh conditions at approximately 1.8km elevation) and increases as visibility degrades. Because the index increases as haze increases, it is characterized as a haziness index. Expressed in terms of extinction coefficient ( $b_{ex}$ ) and visual range ( $vr$ ):

$$\text{haziness } (dv) = 10 \ln (b_{ex}/0.01 \text{ km}^{-1}) = 10 \ln (391 \text{ km}/vr)$$

The name deciview was chosen because of the similarity of the decibel scale in acoustics. Both use 10 times the logarithm of a ratio of a measured physical quantity to a reference value to create scales that are approximately linear with respect to changes as perceived by human senses. Figure 2 shows the relationship between haziness expressed in the  $dv$  scale and extinction coefficient or visual range.

Ideally, a just noticeable change (JNC) in scene visibility should be approximately a one or two  $dv$  change in the deciview scale (i.e., a 10% to 20% fractional change

in extinction coefficient) regardless of the baseline visibility level. Similarly a change of any specific number of  $dv$  should appear to have approximately the same magnitude of visual change on any scene. The degree to which the deciview scale meets these ideals will depend on the extent to which any scene departs from the assumptions required to develop the scale (Pitchford and Malm, 1993).

### APPLICATIONS

The  $dv$  scale provides a convenient, numerical method for presentation of visibility values. Any visibility monitoring data or model predictions that are available in visual range or extinction coefficient are easily converted to the new visibility index expressed in deciview. A few examples were selected to illustrate the value of the  $dv$  scale.

Perhaps the most convincing evidence that the  $dv$  scale is approximately linear with changes in visibility comes from viewing scenic photographs generated using image-processing techniques to display results from radiative transfer modeling (Molenar, et al., 1992). Photographs have been generated which show the effects of varying the extinction coefficient without changes to lighting or scene conditions (Trijonis, et al., 1990). The  $dv$  scale seems to adequately characterize perceived changes in visual conditions except when the assumption of sufficient targets at sensitive distances is violated.

Use of the  $dv$  scale is an appropriate way to compare and combine data from different visibility perception and valuation studies. When results from multiple studies are presented in terms of a common perception index, the effects of survey approach and other factors influential to the results can be evaluated.

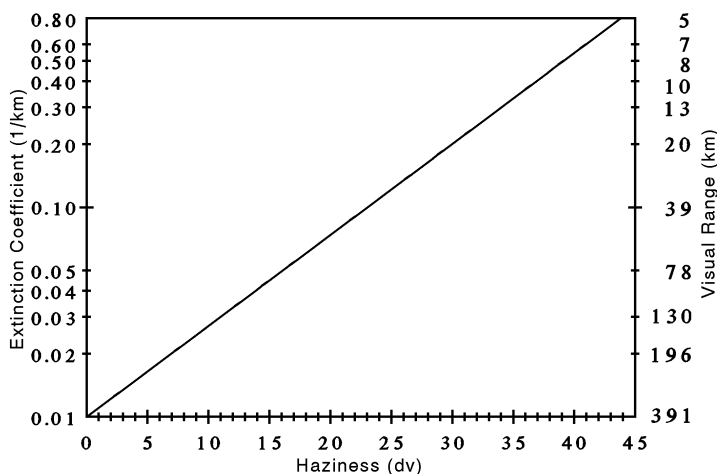
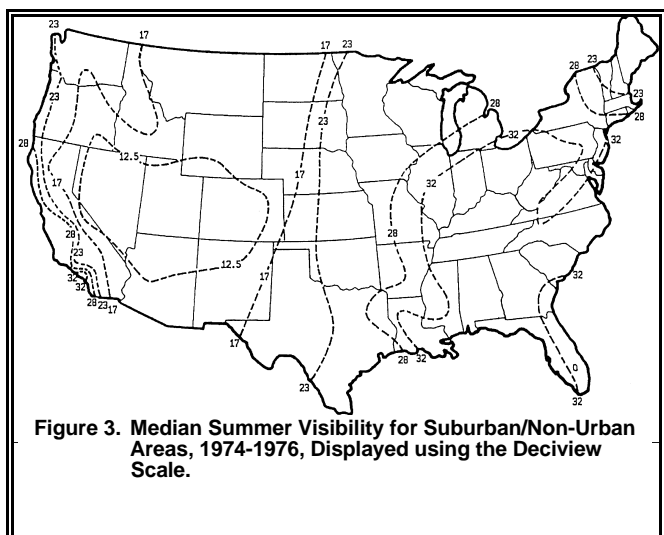


Figure 2. Visual Range and Extinction Coefficient as a Function of Haziness Expressed in Deciview.

Figure 3 is a contour map of median summer visibility for the continental United States. This map was originally produced as a visual range (miles) contour map (Trijonis and Shapland, 1978), and is perhaps the most popular display of visibility conditions ever produced (Environmental Protection Agency, 1979; Trijonis, et al., 1990). The labels on the contour intervals have been converted to  $dv$  to produce Figure 3. The contour lines show an unbiased



representation of the spatial gradient of perceived visibility. The median summer visibility in the relatively clean Colorado Plateau has a  $dv$  value of approximately 12, and median summer visibility in the Eastern U.S. has a  $dv$  value of approximately 32. The use of an index which is linearly related to perceived visibility improves appropriate interpretation of study results when the issue concerns visual effects.

## CONCLUSIONS

A constant, fractional change in the extinction coefficient or visual range is shown to correspond to a similar change in perceived visibility regardless of the baseline visibility levels with the assumption that scenic elements are visible at sensitive distances. Based upon this relationship, a new visibility index is defined in terms of the extinction coefficient (or visual range). A haziness index using the  $dv$  scale has the following properties:

- ▼ deciview ( $dv$ ) units are linear with respect to perceived visibility changes;
- ▼ a 1 to 2 $dv$  difference corresponds to a small, visibly perceptible change in scene appearance where the assumptions used to develop the  $dv$  scale are met;
- ▼ zero (0)  $dv$  represents extremely good visibility (Rayleigh atmosphere where  $b_{ext} = 0.01\text{km}^{-1}$ ); and
- ▼  $dv$  scale increases correspond to greater visibility impairment.

It is appropriate to use the  $dv$  scale to quantify visibility whenever the perceptibility of visibility is at issue. Example uses include assessing the visibility effects of proposed changes in emissions, investigating relationships between societal economic values and visibility, and displaying predicted or measured visibility levels which may influence public policy to decision-makers and the public.

## REFERENCES

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- Trijonis, J.C. and Shapland D. (1978) Existing Visibility Levels in the U.S. Technology Services Corporation Report to the U.S. Environmental Protection Agency, Grant 802815, Research Triangle Park, NC.
- U.S. Environmental Protection Agency (1979) Protecting Visibility: An EPA Report to Congress. Report EPA 450/5-79-008, Washington, D.C.

## VISIBILITY NEWS.....

### PROTECTING VISIBILITY IN WESTERN CANADA AND THE PACIFIC NORTHWEST

A workshop titled, *Protecting Visibility in Western Canada and the Pacific Northwest*, was held in Harrison Hot Springs, British Columbia, from March 14-17, 1993. Contact Peter Reid, BC Environment at 604/371-6296 if you are interested in a synopsis of the workshop.

### USDA FOREST SERVICE INITIATES IMPROVE PROTOCOL MONITORING SITES

The USDA Forest Service is currently planning to install and operate as many as five IMPROVE Protocol sites by fall 1993. The sites will include scene (camera), optical (NGN-2 nephelometer), aerosol (four-stage IMPROVE modular aerosol sampler), and meteorology (temperature and relative humidity) components. Several sites will also collect wind speed and wind direction data. Over the next several years the Forest Service will install and operate additional IMPROVE Protocol sites.

**IMPROVE STEERING COMMITTEE**

IMPROVE Steering Committee members represent their respective agencies and meet periodically to establish and evaluate program goals and actions. IMPROVE-related questions within agencies should be directed to the agency's Steering Committee representative. Steering Committee representatives are:

**U.S. EPA**

Marc Pitchford  
Environmental Monitoring  
Systems Lab  
P.O. Box 93478  
Las Vegas, NV 89193-3478  
702/895-0432 (Phone)  
702/895-0496 (Fax)

**U.S. EPA**

Joe Elkins  
MD-14  
OAQPS  
Research Triangle Park, NC  
27711  
919/541-5653 (Phone)  
919/541-2357 (Fax)

**NPS**

William Malm  
NPS-AIR  
Colorado State University  
CIRA - Foothills Campus  
Fort Collins, CO 80523  
303/491-8292 (Phone)

**BLM**

Scott Archer  
Service Center (SC-212A)  
P.O. Box 25047  
Denver, CO 80225-0047  
303/236-6400 (Phone)  
303/236-3508 (Fax)

**USFS**

Rich Fisher  
Air Specialist, Wash. Office  
Rocky Mtn. Experiment Sta.  
240 W. Prospect  
Fort Collins, CO 80526  
303/498-1232 (Phone)  
303/323-1010 (Fax)

**FWS**

Sandra Silva  
Fish and Wildlife Service  
P.O. Box 25287  
Denver, CO 80225  
303/969-2814 (Phone)  
303/969-2822 (Fax)

**NESCAUM**

Rich Poirot  
VT Agency of Nat. Res.  
103 South Main Street  
Building 3 South  
Waterbury, VT 05676  
802/244-8731 (Phone)  
802/244-5141 (Fax)

**STAPPA**

Dan Ely  
Colorado Dept. of Health  
Air Pollution Control Div.  
4300 Cherry Creek Drive S.  
Denver, CO 80222-1530  
303/692-3228 (Phone)  
303/692-5493 (Fax)

**WESTAR**

John Core  
Executive Director  
1001 S.W. 5th Ave.,  
Suite 1000  
Portland, OR 97204  
503/220-1660 (Phone)  
503/220-1651 (Fax)

**PREVIEW OF UPCOMING ISSUE . . .**

The next IMPROVE Newsletter will be published in July 1993, and will include:

- v Network Status for the Spring 1993 Season
- v **FEATURE ARTICLE:** Highlights from the NAS report "Protecting Visibility in National Parks and Wildernesses."

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Your input to the IMPROVE Newsletter is always welcome. For more information, address corrections, or to receive the IMPROVE Newsletter, contact:

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303/484-7941 Phone  
303/484-3423 Fax

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1901 Sharp Point Drive, Suite E  
Fort Collins, CO 80525

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